The Role of Organic Sea Salt Aerosol in Cloud Processing

Lynn M. Russell
Department of Chemical Engineering
Princeton University
Princeton, NJ 08544
phone: (609) 258-1144 fax: (609) 258-0211 email: lrussell@princeton.edu
Award #: N00014-98-0565
http://www.princeton.edu/~aerosol/

LONG-TERM GOAL

My long term goal is to quantify the role of organic compounds in sea salt aerosol. This project studies the effect of organic compounds on the uptake of water by sea salt aerosol particles. Studying the chemical composition of those particles provides important information about their behavior in the atmosphere.

OBJECTIVES

I want to know what role the presence of organic species may play in the hygroscopicity of particles. In particular, I want to know how the organic composition of particles affects their ability to serve as cloud condensation nuclei.

APPROACH

We have studied the empirical relationship between the organic composition of particles and their size. We are now constructing a thermodynamic model that accounts for the effect of organics on the uptake of water by particles.

We will also develop an enhanced method of measuring the organic fraction of particles, in order to collect airborne measurements of the organic fraction of particles.

WORK COMPLETED

Analyses of organic matter in particles collected during ACE 2 was completed and has been accepted for publication (Schmeling et al.).

RESULTS

While there is evidence that the ambient concentration of the coarse fraction of sea salt particles depends strongly on wind speed, the comparison with existing parameterizations is weak. In addition, there is some evidence that a large fraction of the organic material present in clean marine conditions is associated with sea salt.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1999		**00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Role of Organic Sea Salt Aerosol in Cloud Processing	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Princeton University,Department of Chemical Engineering,Princeton,NJ,08544**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

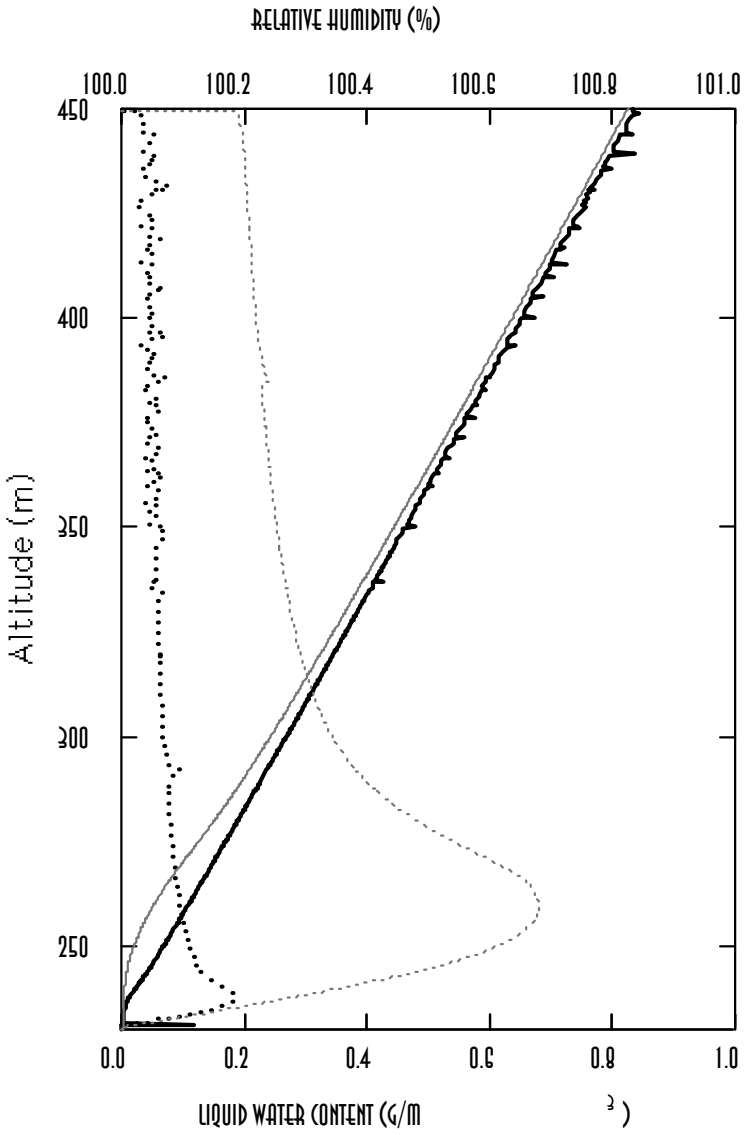
13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Ship tracks are a natural laboratory to isolate the effect of anthropogenic aerosol emissions on cloud properties (Russell et al., 1999). The Monterey Area Ship Tracks (MAST) experiment in the Pacific Ocean west of Monterey, California, in June 1994, provides an unprecedented data set for evaluating our understanding of the formation and persistence of the anomalous cloud features that characterize ship tracks. The data set includes conditions in which the marine boundary layer is both clean and continentally-influenced. Two case studies during the MAST experiment are examined with a detailed aerosol microphysical model that considers an external mixture of independent particle populations. The model allows tracking individual particles through condensational and coagulational growth to identify the source of cloud condensation nuclei (CCN). In addition, a cloud microphysics model was employed to study specific effects of precipitation. Predictions and observations reveal important differences between clean (particle concentrations below 150 cm^{-3}) and continentally-influenced (particle concentrations above 400 cm^{-3}) background conditions: in the continentally-influenced conditions there is a smaller change in the cloud effective radius, drop number and liquid water content in the ship track relative to the background than in the clean marine case. The figure below illustrates the change in cloud liquid water content between the background (solid grey line) and the track (solid black line).



Predictions of changes in cloud droplet number concentrations and effective radii are consistent with observations although there is significant uncertainty in the absolute concentrations due to a lack of measurements of the plume dilution. Gas-to-particle conversion of sulfur species produced by the combustion of ship fuel is predicted to be important in supplying soluble aerosol mass to combustion-generated particles, so as to render them available as CCN. Studies of the impact of these changes on the cloud's potential to precipitate concluded that more complex dynamical processes must be represented to allow sufficiently long drop activations for drizzle droplets to form.

Polycyclic aromatic hydrocarbons (PAHs) have been sampled in marine stratus conditions to identify the contribution of anthropogenic combustion emissions in activation of aerosol to cloud droplets (Russell et al., 2000). The Monterey Area Ship Track (MAST) Experiment provided an opportunity to acquire data on the role of organic compounds in ambient clouds and in ship tracks identified in satellite images. Identification of PAHs in cloud droplet residual samples indicates that several PAHs

are present in cloud condensation nuclei in anthropogenically-influenced air, and do result in activated droplets in cloud. These results establish the presence of combustion products, such as PAHs, in submicrometer aerosols in anthropogenically-influenced marine air, with enhanced concentrations in air polluted by ship effluent. The presence of PAHs in droplet residuals in anthropogenically-influenced air masses indicates that some fraction of those combustion products is present in CCN that activate in cloud. Although a sufficient mass of droplet residuals was not collected to establish a similar role for organics from measurements in satellite-identified ship tracks, the available evidence from the fraction of organics present in the interstitial aerosol is consistent with part of the organic fraction partitioning to the droplet population. In addition, the probability that a compound will be found in cloud droplets rather than in the unactivated aerosol and the compound's water solubility are compared (as shown in the graph below). The PAHs studied are only weakly soluble in water, but most of the sparse data collected support more soluble compounds having a higher probability of activation.

Activation Index
Solubility (M)
at 300K
at 293K
0
1
2
3
4
5
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
anthracene
phenanthrene
fluoranthene
pyrene
benz[a]anthracene
chrysene
triphenylene
benzo[a]pyrene
benzo[k]fluoranthene
benzo[e]pyrene
perylene

IMPACT/APPLICATION

This work has applications for determining the role of organic compounds in aerosol scattering. By assessing the contribution of organic mass to particles in field measurements we will be able to quantify the role of orgnic species in continentally-influenced aerosol populations.

TRANSITIONS

We expect that the method we are currently developing for organic analysis will be used in future field campaigns.

RELATED PROJECTS

1 – The relationship between particle number and organic mass was studied in collaboration with Dean Hegg (University of Washington). This study incorporated the results of our measurements of the organic fraction of particles from ACE 2.

PUBLICATIONS

Russell, L.M., K.J. Noone, R.J. Ferek, R.A. Pockalny, R.C. Flagan, and J.H. Seinfeld: Combustion Organic Aerosol as Cloud Condensation Nuclei in Ship Tracks, Journal of the Atmospheric Sciences, in press (2000).

Russell, L.M., J.H. Seinfeld, R.C. Flagan, R.J. Ferek, D.A. Hegg, P.V. Hobbs, W. Wobrock, A. Flossmann, C.D. O'Dowd, K.E. Nielsen, and P.A. Durkee: Aerosol Dynamics in Ship Tracks, Journal of Geophysical Research – Atmospheres, in press (1999).

Schmeling, M., L.M. Russell, C. Erlick, D.R. Collins, H. Jonsson, Q. Wang, P. Kregsamer, and C. Streli: Aerosol Particle Chemical Characteristics Measured from Aircraft in the Lower Troposphere during ACE 2, Tellus, in press (2000).